DOCUMENT RESUME

ED 223 236 IR 010 487

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TITLE Status and Trends in Visual Information Processing.
PUB DATE May 82
NOTE 33p.; Paper presented at the Annual Meeting of the Association for Educational Communications and Technology, Research and Theory Division (Dallas, TX, May 1982). For other papers, see IR 010 442-487.
PUB TYPE Information Analyses (070) -- Viewpoints (120) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Cognitive Processes; *Cognitive Style; *Individual Differences; Instructional Materials; Intermode Differences; Learning Modalities; Literature Reviews; Media Research; *Modeling (Psychology); *Prompting
IDENTIFIERS *AECT Research and Theory Division Meeting; *Learning Strategies; Stimulus Characteristics

ABSTRACT

Relationships between media format, sensory channel, and cognitive information processing are not straightforward. Media format does not determine information processing and storage except when a deliberate attempt is made to model cognitive processes by manipulating the medium. Sensory channel only affects processing and learning for relatively low-level tasks, because information presented in various media formats and sensory channels is mediated by the learner's mental skills and the learning strategies used. A model can geographically show relationships among cognitive processes, mental skills, and learning strategies. Expansion of this model to include processing control through modeling and instruction in skills and strategies must include research in instruction. For learners lacking skills and ability to select the best strategy, instruction should control learning strategies by modeling the cognitive process needed for the task. Instructional systems can also assign particular strategies for learners with some skill but without the necessary metacognitive processes required for wise strategy deployment. For high ability learners, capable of assigning the appropriate strategy independently, specific directions are unnecessary. A review of research supports this viewpoint. (LMM)

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Status and Trends in Visual Information Processing.

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Presented at the annual convention of AECT, Dallas, May, 1982.

IR010 487

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There is considerable confusion in our area as to what visual information processing really is. It is instructive to make a list of the various "dichotomies" that run through our research literature, and to discover that many researchers are not only unsure about what is related to what, but often claim relationships among categories of variables that do not have any empirical support. Such a list would include, among other dichotomies, "Visual" versus "Audio", "Pictorial" versus "Verbal", "Simultaneous" versus "Successive", and "Image" versus "Proposition". When these dichotomies are presented baldly like this, shawn of the verbal packaging in which they are couched in research papers, it becomes clear that each belongs to a different category of phenomena, and because of this they are difficult to link either conceptually or empirically. The "Visual-Audio" adjective pair refers to sensory channel, "Pictorial-Verbal" to media format, "Simultaneous-Successive" to ways in which information is processed, and "Image-Proposition" to forms in which information is represented internally.

These four dichotomies fall naturally into two groups on the basis of how they relate to learning. Superficially, sensory channels and media format have to do with processes external to the learner. The selection of audio or visual channels through which information is presented, and the selection of pictorial or verbal signs (Knowlton, 1966) by means of which concepts are

expressed, are usually under the control of the instructional designer or the instructor. On the other hand, the processes that are brought to bear on this information, and the way in which that information is represented internally, are under the control of the learner (Neisser, 1976; Salomon, 1979; Winn, 1981b). (It should be noted that the word "control" does not imply conscious processing in the sense in which it is used by Schneider and Shiffrin (1977). Processing and representation can be either automatic or controlled, as will be seen later.) More specifically, the channel and format that the information is presented in help determine the "perceived demand characteristics" of the task (Salomon, 1981, 1982), which determine how much mental effort a learner will invest, and how much will be learned. However, since, according to Salomon, the demands of the task are those that are attributed to it by the learner, the actual processes applied to the information and the way in which it is represented as schemata results from an interaction between channel and media format and the perception of them by the learner. So the major difference between phenomena that can be labelled "visual-audio" or "pictorial verbal", and those that can be called "simultaneous-successive" or "imaginal-propositional" lies in the fact that the first two dichotomies have to do with the way tasks are presented to learners, while the second two have to do with the way the learner reacts to what the task is perceived to be.

In spite of this major difference between the two types of dichotomy in terms of the learning task and how it is perceived, many researchers still cling to the hypothesis that these four dichotomies are related. It is, after all, intuitively appealing to suppose that pictorial media, presented in the visual channel, are processed simultaneously and stored as images, and to suppose that verbal media, presented in the audio channel, are processed successively, and stored as propositions. However, this hypothesis is somewhat naive. Cognitive processes are not always determined by media format and channel, and when they are, the learning tasks tend to be not very demanding intellectually. What is more, there is no certainty that information that is processed simultaneously will be stored as images.

There is evidence in research that supports these claims. For instance, the link between media format and type of processing has been shown to be tenuous. Kirby and Das (1978) found that whether written text was processed simultaneously or successively depended upon the amount of effort subjects had to put into comprehension of the text, that is upon the nature of the task. Intuitively, people tend to think of reading as a linear, successive process. However, Kirby and Das found this to be so only when the text was easy to comprehend. With more difficult materials, more simultaneous processing was required than successive. Other examples of the failure of research to establish clean relationships between media format and mental

skills and processes have been presented by Cronbach and Snow (1977, chapter 9). There is an important exception to this though. Media format does influence processing when the media are designed deliberately to model the cognitive processes that the learner should use if learning is to be optimal. Salomon's (1974) studies of using zooms in film to model the process of mentally moving from a general overview to details of visual displays offer examples of the modelling process. This theme will be returned to later in the paper.

As far as the relationship between sensory channel and processing is concerned, it appears that the link exists only for certain types of relatively low-level learning. Das and his colleagues (Das, Kirby and Jarman, 1975, 1979) have based their theory of simultaneous and successive cognitive synthesis in large part upon neurological evidence (Luria, 1970, 1973). Das and Jarman (1981) suggest that three cortical zones, identified by Luria, deal with sensory modality in hierarchical fashion. The primary zones are modality specific in the way they deal with information. The secondary zones serve to integrate information between sensory modalities. The tertiary zones deal with information across all modalities regardless of provenance. Das and Jarman offer empirical evidence suggesting that as information moves from one zone to the next, and as modaltiy specificity is lost, high-order analysis of information becomes possible. They even equate high intelligence with the ability to

integrate information across modalities (1981, p. 312).

Thus, modality specificity is transcended for higher-level tasks, but need not be so for low-level tasks. An example of the latter is to be found in a study by Metcalfe, Glavanov and Murdoch (1981), where an interaction between modality and type of information recalled was found. It was reported that visual input resulted in better recall of spatial information, while auditory input led to better recall of temporal information. However, the task was recall, which is not as high-level a skill as reading a text.

In summary, it can be stated that the relationships between media format and sensory channel, and the way in which information is processed, are not straightforward as the "naive" hypothesis would have us believe. Media format does not determine how information is processed and stored, except when a deliberate attempt is made to model cognitive processes by manipulating the medium. Sensory channel only affects processing and learning for relatively low-level tasks. The reason for this is that the influence of format and modality on cognitive processes is indirect, being mediated by the learner's intellectual skills and the learning strategies the learner is using at the time. This is best explained graphically, and a model showing relationships among cognitive processes, mental skills and learning strategies is shown in figure 1.

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Figure 1 about here

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In this model, it is suggested that we all have the potential for using the same cognitive processes. However, only in some of them can we claim to be "mentally skilled". And even if we do possess the mental skills that are relevant for a particular learning task, we do not necessarily employ them as learning strategies when it is appropriate to do so. The broader implications of this model have been described elsewhere (Winn, 1982a), and will not be discussed here, beyond mentioning that instruction must aim at developing mental and strategic skills in learners as well as transmitting content. What is important for the present discussion, though, is the notion that instruction does not have a direct impact on cognitive processes. Any medium we present in any channel will only engage processes that the learner is skilled in and employs as a learning strategy at the particular time the material is presented. Without controlling skills and strategies (through modelling, or through instructions on how to learn, for example), there can be no certain cause and effect relationships between sensory modality or media format and cognitive processing or internal representation.

The discussion so far has not done much to remove the

confusion surrounding the question of what visual information processing really is. However, many of the problems encountered by researchers in this area, and many of the concerns about the "naive" hypothesis about the four dichotomies, have been described. What this paper is really about, then, turns out to be simultaneous and successive processing of pictorial and verbal media presented in either channel, and stored as images or propositions. In other words, it is about learning and processing in general. Indeed, the more one studies cognitive psychology, the more one realizes that to separate learning from media from any other type of learning is arbitrary and counter-productive.

It is now time to look at the present state and discernible trends in research into information processing in our field. As the model presented above suggests, this is research that is concerned with cognitive processes, mental skills and learning strategies. If the model is extended to include the control of processing through modelling and instruction in skills and strategies, then research in instruction must also be included. While a number of scholars have addressed these issues (Salomon, 1979; Winn, 1982a; Clark, 1982; Bovy, 1981; Clark and Bovy, 1981), the approach taken by Bovy (1981) will serve as a basis for the following analysis.

Underlying Bovy's discussion is Rigney's (1978) theory of detached and embedded strategies. Embedded strategies are those

that are a part of instruction itself, and which model, in ways mentioned above, the cognitive processes the learner is best advised to employ. Detached strategies are not part of the instruction in the same way, but are additional indications as to how the learner is to process the information that is presented. Thus, films, like Salomon's, that model, through zooming, the cognitive process of moving in on details of visual displays, are employing embedded strategies. Instructions to learners to learn maps by dividing them into quadrants (Thorndyke and Stasz, 1980) are not "embedded" in the maps themselves, and operate as detached strategies. Rigney further distinguishes between detached strategies that are "system assigned", and those that are "learner-assigned". In a system-assigned strategy, directions for processing are given as part of the instruction the learner receives (as, for example, instructions on how to partition maps). A learner-assigned strategy is one that the learner decides to use without prompting.

The most important feature of Bovy's approach for the present discussion is the association of embedded, system-assigned and learner-assigned strategies with learner ability. (Here, ability is taken to be facility with cognitive processes, not scores on aptitude tests!) Bovy claims that low-ability learners need to use embedded strategies, because they have to be shown how to process the information they are to learn. Middle-ability learners do not need this degree of

support, but nonetheless need system-assigned strategies to tell them which particular skills to bring to bear on the task. Finally, high-ability learners are quite capable of deciding for themselves which learning strategy to employ. Modelling, or assigning detached strategies, could even interfere with the way they learn.

It is useful to point out links between these ideas and some of the things we have discussed above. In terms of our model, we might say that low-ability learners have only the potential for using cognitive processes appropriately. They possess the processes, but have not yet been able to translate them into skills and strategies. Middle-ability learners possess certain mental skills, but have not yet been able to develop the strategies that will allow their judicious deployment. High-ability learners possess both skills and the ability to use them as strategies. Implicit in this is a hierarchical structure. You have to have relevant mental skills before you can acquire and apply learning strategies. You have to have the potential for using cognitive processes before you can acquire mental skills. Looking at it from the point of view of instruction, embedded strategies need to demonstrate processes, skills and strategies for their deployment. System-assigned strategies describe both the strategy and when to use it.

It should be noted that often embedded strategies are not

sufficiently direct in telling learners when they should be used. For example, Gick and Holyoak (1980) modelled a particular problem-solving strategy which failed to transfer to a second problem that was analogically identical to the first. However, when learners were prompted to solve the second problem in the same way that they had solved the first, they succeeded. Similar results, indicating the need for system assigned strategies to accompany modelling in studies of learning by analogy, have been reported by Reed, Ernst and Banerji (1974).

When looking at the research in these areas, we must not lose sight of the fact that strategies of any kind are determined primarily by the learning task. In the case of learner-assigned strategies, this pretty much means the perceived demand characteristics (Salomon 1981, 1982) of the task. In system-assigned and embedded strategies, the strategies are selected, more likely then not, on the basis of a task analysis performed by the designer or instructor. It is therefore important to consider the nature of the task in the following discussion. With this in mind, we will now look at research in embedded, system-assigned and learner-assigned strategies (involving cognitive processes, mental skills and learning strategies).

Embedded Strategies.

A great deal of research has been carried out in our area to do with the effect of pictures and more generally visual materials on learning. This research has been summarized elsewhere (Fleming and Levie, 1978; Levie and Dickie, 1973; Dwyer, 1972, 1978), and will not be presented here. When pictorial treatments have been found to be superior to non-pictorial treatments, results have been interpreted to support either a "realism" theory or a "cueing" theory of learning. The first claims that pictorial materials are effective because they present information in ways that make it easy for the learner to recognize concepts. Cueing theory supposes that using graphic cues, such as color or arrows or underlining, make learning concepts easier by drawing attention to their critical attributes.

Recognition and concept learning are different types of learning. As a result, pictorial materials designed to teach recognition of old concepts and the acquisition of new ones should model different types of cognitive process. However, realism theories and cueing theories (summarized by Dwyer, 1972, 1978) have never traditionally been conceived of in terms of modelling cognitive processes. They embody the belief of the naive hypothesis that there is a direct link between media format and learning. As Salomon has suggested, such a belief ignores the role of the learner in interpreting and attributing meaning to

the appropriate strategy on their own. We looked at some research that supports this approach.

It should be obvious by now that I consider the most useful direction to follow to be that pointed to by such work as that of Clark and Bovy, and Salomon. The study of information processing of all kinds has been convincing in showing that concerns with media format and sensory channel are largely misplaced by researchers in our area, because, when all is said and done, they do not make all that much difference on their own. We should, as Clark (1982) has suggested, make clearer distinctions between media and methods. While materials may be produced, exploiting channel and sign differences of the various media, they will only be effective if they model the cognitive processes that learners should be using. And even then, modelling alone may not be sufficient. Some learners will require even further guidance, through detached strategies, before the modeled processes can be transferred to the task to be learned. What is more, learners need to be told strategies by the instructional system unless they are highly able. It is not sufficient simply to show a learner a diagram and expect him to process it simultaneously.

This paper has said virtually nothing about how information is represented. The "imagery debate" is still alive and well (Kosslyn, 1981; Pylyshyn, 1981), and clearly more research will be needed before the issue is resolved. However, as I have

pointed out before (Winn, 1980a), it is not really necessary for us to resolve the matter in order to continue our work on information processing and ability. I continue to believe that how information is represented in memory is determined, just as processing strategy is determined, by the perceived nature of the learning task. This view is consistent with most of what has been said above. Until we understand more fully the relationships that exist among the perception of demand characteristics of learning tasks, ability and processing, we will still be flying by the seat of our pants when it comes to instructing and instructional design. Let us not get ensnared with research into media formats, but let us look rather at internal processes and interactions, where what the learner does really makes a difference.

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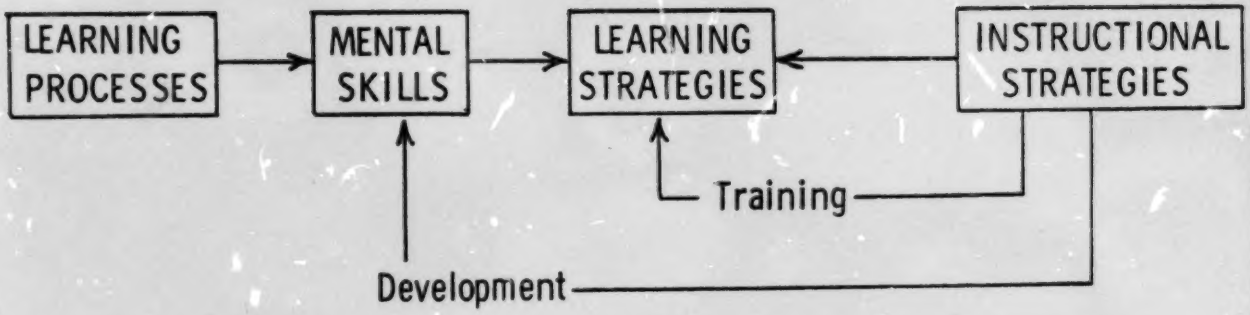

Figure 1. Model of Learning and Instruction.

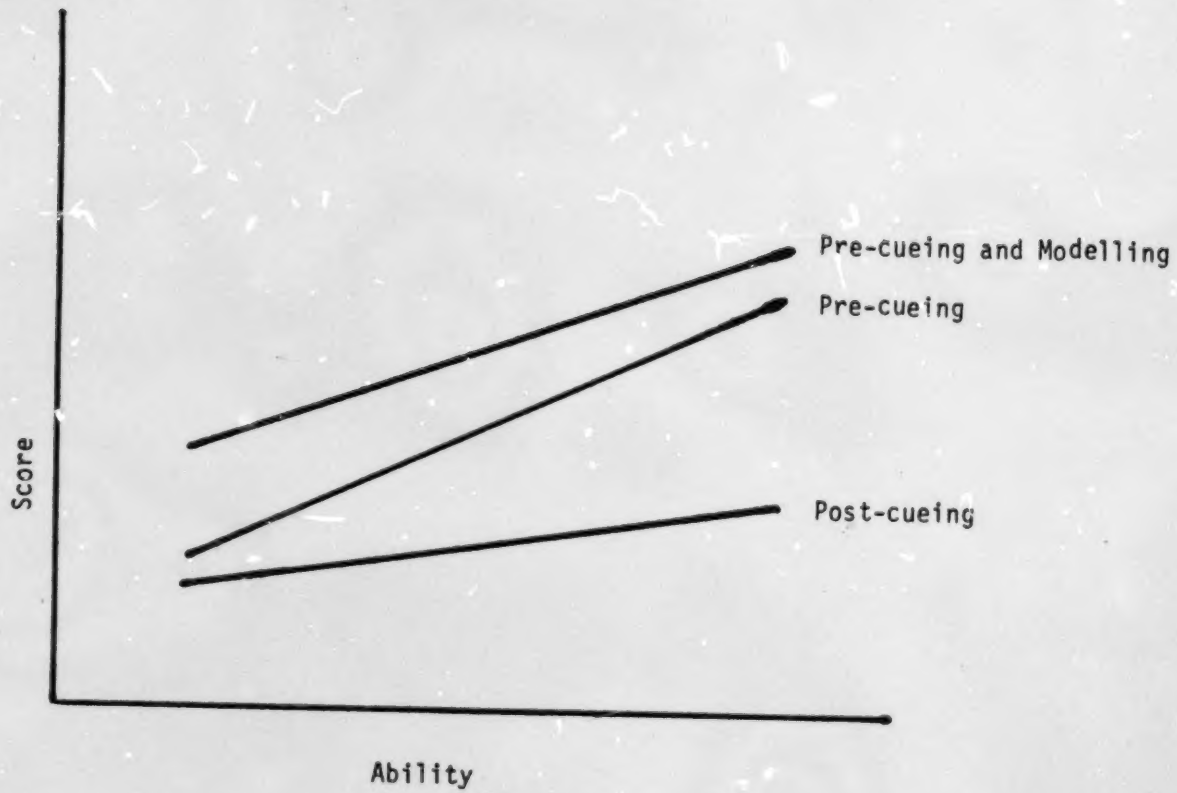

Figure 2. Interaction of Instructional Strategy Types and Ability.

information (Salomon, 1979). Where pictorial treatments have been successful, they probably modelled cognitive processes without the researchers deliberately intending that they should. As Bovy (1981) has stated, there is a need to relate cognitive processing to external stimuli.

In studies where researchers have attempted to model processes, pictorial materials have been successful in teaching. In a study that required grade nine students to learn about the evolution of dinosaurs, Winn (1982b) varied the degree to which classifying processes were modelled. When pictorial diagrams were presented, showing the dinosaurs evolving left to right across the page, category names were encountered by subjects, reading naturally from left to right, before the names of each particular member of the category. This modelled a deductive process for learning concepts, which has generally been found to be effective. When the diagram was reversed, modelling ineffective processes where instances were processed before categories had been set up for them, learning was far less successful. Royer and Cable (1975, 1976) modelled analogical thinking by likening metal structure, through which heat flowed, to tinker-toy constructions. Learners were thus encouraged to establish an analogical association between the new information and schemata that they presumably already possessed. Dean and Kulhavy (1981) showed that forcing learners to employ certain cognitive processes, by having them draw maps of a territory they were to

learn about, improved learning. Drawing the map both modelled for them, and forced them to employ, spatial cognitive strategies, and improved their performance.

System Assigned Strategies.

These are just some examples of how embedded strategies can successfully model cognitive processes in order to tell learners how to process information and improve their performance. In each of these cases, we can assume that performance was superior when compared to that of subjects who did not experience embedded strategies because the modelling showed them precisely what processes to employ. However, with learners who already possess the mental skills needed to learn, all that is necessary is to tell them which skills to apply as learning strategies. An interesting example of this is offered in a study by Cramer (1981) using the time-tried interactive imagery strategy for learning word paired associates. Many studies have shown that instructions to form interactive images, in which the two concepts in the pair have a memorable relationship with each other, improve recall. The interesting innovation in Cramer's study was that the effectiveness of the imagery strategy was compared for first and fifth grade subjects. Imagery instructions improved the performance of the fifth-graders more than that of the first-graders, which suggests that when subjects, like the first-graders, do not possess the necessary skills,

system-assigned strategies are effective. This suggestion is borne out by the fact that some of the first-graders were capable of using the imagery technique, and these performed better than their age-mates. This study illustrates part of the general principle that learners of low (or no) ability cannot learn from system-assigned strategies, while those who do possess the necessary skills, can process the information effectively.

Other studies offer further illustration of this point. Weinstein (1978) taught subjects a "loci" strategy based upon features of a university campus, and this was shown to improve recall of words in a list. Thorndyke and Stasz (1980) taught subjects effective map-learning strategies, such as partitioning and rehearsal, and these too improved learner performance. Alesandrini (1981) instructed subjects to write paraphrases of texts on the battery, or to draw pictures from the text. These strategies improved learning, while instructions to process the information either analytically, by focussing on details, or holistically, by relating specifics to more inclusive concepts, did not change performance. (The nature and effectiveness of system-assigned strategies has been discussed in more detail by Winn (1982a) and Bovy (1981).

Learner Assigned Strategies.

There have generally been two types of aptitude-treatment interaction found in research. The first type has supported the hypothesis that elaborated instructional materials assist students of low ability. The rationale behind this is that, as Salomon has suggested (1979), the materials do the work for the learners that they are unable to do for themselves. A typical example of this is to be found in a study by Holliday, Brunner and Donais (1977) in which adding a diagram to a text improved learning in low-verbal subjects more than it did in high-verbals. It is also this promise that underlies a lot of the studies summarized by Allen (1975). A second type of ATI has suggested an alternative hypothesis. Here, elaborated materials have improved the learning of high-ability subjects. Winn (1980b) found, contrary to Holliday et. al., that the addition of a diagram to a text improved the performance of high-ability and not low-ability learners. Similarly, in another study, Winn (1981a) found that adding arrows to cue critical attributes of concepts, only helped high-ability subjects. The difference between Holliday et. al. and Winn's diagrams lay in the degree to which they were elaborated. Holliday's diagrams were complex flow-charts, with small pictures added, illustrating the concepts of biochemical cycles. Winn's diagrams were block-word diagrams containing far less detailed information, about food chains and insect

metamorphosis. It is therefore quite likely that, though of the same general character, the two sets of diagrams functioned in entirely different ways, with Holliday's complex diagrams supplanting through their informational richness weak or absent mental skills, while Winn's diagrams, containing far less information, merely activated skills that were already present.

These studies suggest that picture-like materials sometimes model cognitive processes for low-ability learners, and at other times cue high-ability learners as to which strategy they should apply. In other words, they cover the whole range of embedded and detached strategies. The study by Dean and Kulhavy (1981), mentioned briefly above, studied all three types of strategy at once. In their second experiment, these researchers divided the subjects into three groups, each of which had to learn information presented on a map. Each group had to read a text containing information about a fictitious country. In addition to the text, the first "forced-organizer" group had to label an outline map by copying from a complete map projected on a screen. The second "subject-controlled organizer" group were given a map that had already been labelled for them. The third group was simply presented with the text about the territory. Using our terminology, appropriate cognitive processes were modelled for the forced-organizer group, by compelling the subjects to process the information in a certain way. For the subject-controlled organizer group, the presence of the map served merely as a

suggestion that they process the information spatially. The last, text-only, treatment provided no information about strategy at all, leaving learners to do the task any way they thought best. This was essentially a subject-assigned strategy. The results showed that modelling increased learning. However, there were no differences between the subject-controlled organizer and text-only groups. An ATI suggested that forced processing helped low-verbal students more than high verbals.

The failure of Dean and Kulhavy to find an ATI between system-assigned and learner-assigned strategy treatments with ability as the predictor suggests that, in this case, either providing subjects with a labelled map did not help them learn the information, or that the high-ability learners were not capable of selecting the appropriate strategy for learning. The problem seems, therefore, to lie in the way in which the subjects were cued as to which strategy to use. This problem has been addressed directly in a recent study by Winn (1982c). Subjects were shown series of eight letters that appeared sequentially for 1.5 seconds each at random locations on a computer screen. The task was either to draw the patterns the letters formed, by marking X's on a pad of paper, or to write the letters down in the order in which they occurred. These tasks are clearly either simultaneous (draw patterns) or successive (draw sequence), and were chosen because they draw on two distinct sets of cognitive processes (Das, Kirby and Jarman, 1975, 1979). One group of

subjects were told which task to perform before the letters were presented (a system-assigned strategy) by cueing them with the word "pattern" or "sequence" in the center of the screen. A second group was cued after the letters had been presented, leaving any decisions about strategy up to the subjects, as they did not know from one trial to the next what the task was to be. A third group of subjects, in addition to being precued, was given an elaborate set of instructions, with as much practice as they wanted, on how to perform each of the two tasks. Thus cognitive processes were modelled for them, and practiced. For the simultaneous task, they were shown how to divide the screen mentally into quadrants, and to learn the corner of the quadrant, and the quadrant, in which each letter occurred. A partitioning strategy was found to be successful by Thorndyke and Stasz (1980) for learning maps, a not dissimilar task. Subjects in this third group were also trained to learn sequences of letters (the successive task) by forming chunks of four letters, and rehearsing them covertly. The results of the experiment showed that cueing plus instructions was more effective for both tasks than precueing alone, and that precueing was superior to postcueing. In addition, ATI's were found between tests of simultaneous (figure copying) and successive (digit span) processing and the three treatments. These interactions indicated that modelling through partitioning and chunking helped all ability levels equally on both tasks, but that, for both tasks, precueing alone helped high ability subjects far more than those

of low ability. These results are illustrated in figure 2.

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Figure 2 about here

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The results of this study suggest that embedded strategies that model cognitive processes help both high and low-ability subjects equally, and that with system-assigned strategies, high-ability subjects are capable of selecting appropriate strategies on their own while low-ability subjects are not. The Dean and Kulhavy study, it will be remembered, found that embedded strategies helped low-ability learners more than the highs, but that system and learner-assigned strategies did not have different effects on learning. Each of these studies therefore provides evidence for one part of the Bovy theory. That neither provided support for all of the theory suggests that more research needs to be done in this area, especially since the results seem partly to contradict each other. However, it is quite likely that differences in performance as a function of type of strategy interacting with ability are very much related to specific tasks. And the tasks in the two experiments were really quite different. It should also be noted that Winn's task was much more controlled and "clinical" than Dean and Kulhavy's, which suggests that different types of relationships might

pertain when one looks at cognitive processes in pretty "pure" form than when tasks are closer to "classroom" learning in nature.

Conclusions.

Where does this leave us? What are the present state and current trends in visual information processing? The paper has provided some indirect answers to this question, but, more important, it has looked at some of the current thinking and research in the more general area of information processing as it relates to our area. The first thing to note is that the phrase "visual information processing" is not all that useful. This is because it is not easy, and certainly not very productive, to separate the processing of visual material from other kinds of processing. What is more, the equation of "visual" with "pictorial" is doubly misleading. In the first instance, "visual" refers to sensory systems and "pictorial" to media format. Second, as we have seen, there is no guarantee that presentation of information exploiting either variety of sensory channel or of media format has an effect on processing and learning.

A problem therefore arises from what has been referred to as the "naive hypotheses". This hypothesis suggests that the four "dichotomies" involving sensory channel, media format, type of processing and the way in which information is represented by

learners internally, are all related. By and large, such a relationship does not exist, and on those few occasions when research has provided support for it, the learning tasks have been relatively low-level, and have not required much mental effort to translate the information into higher-order and more abstract structures. Many respected researchers now believe that the way information is processed depends upon what the learner perceives the task to be and the amount of effort he should invest in it. The nature of the task determines information processing as much as learner ability.

Information presented in various media formats and sensory channels is mediated by the mental skills that learners possess and by the learning strategies that they bring to bear upon the task. It is therefore important for instruction to control learning strategies. This can be achieved in a number of ways. Instruction can model the cognitive processes learners are expected to bring to bear on the task. This strategy is appropriate for learners who possess neither the repertoire of skills nor of ability to be able to select the best strategy. Instructional systems can "assign" a particular strategy. This works for learners who possess a degree of necessary skill, but who do not yet possess the necessary metacognitive processes required for wise strategy deployment. Finally, with high-ability learners, instruction need not give specific directions as to strategy at all. These learners are quite capable of "assigning"